Rapid Transfer Update

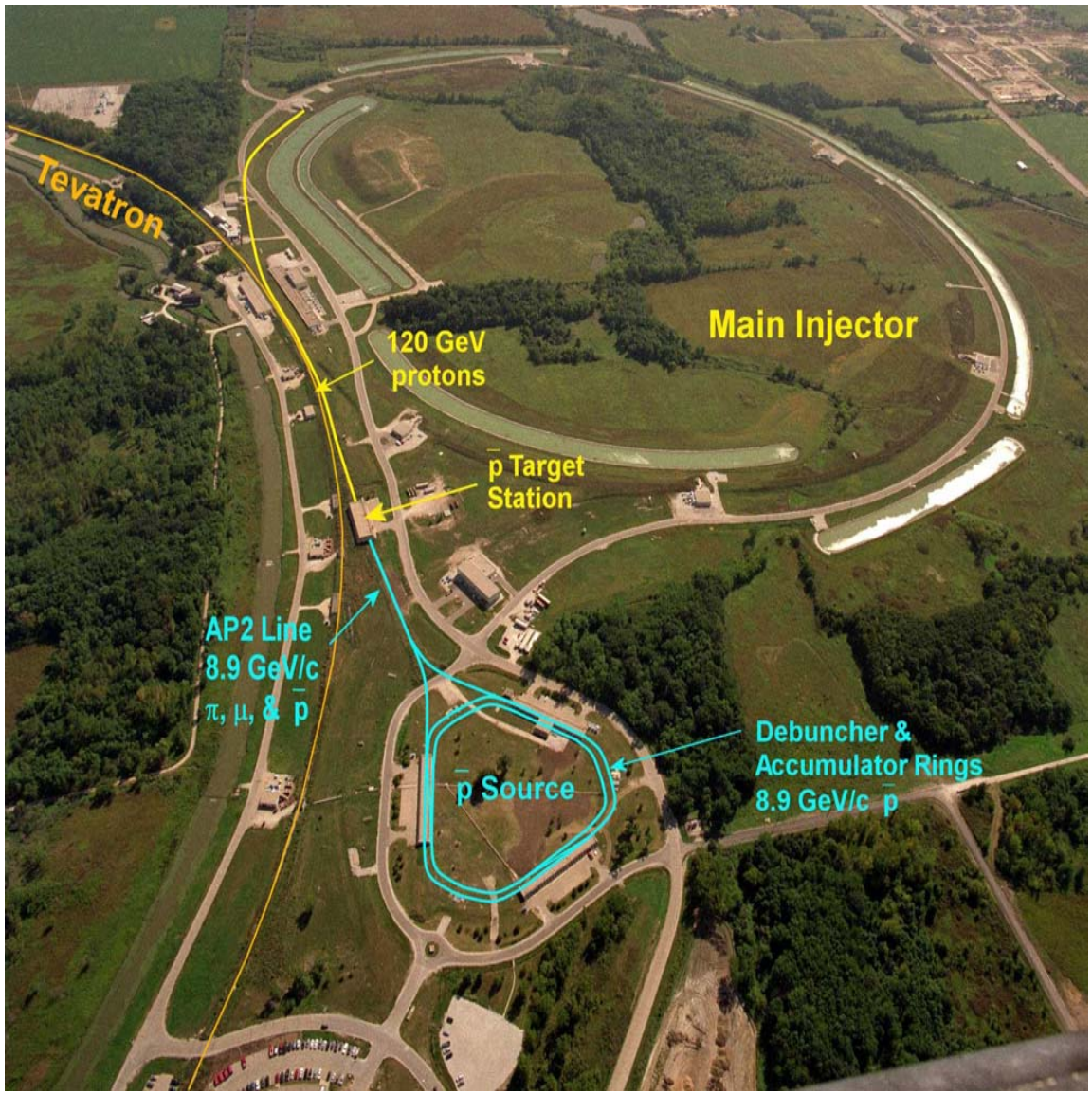
Cons Gattuso

December 18, 2006

Acknowledgements

- Rapid Transfer Task Force
  - Task Force Coordinator
    - Cons Gattuso
      - Pbar Source
        - » Dave Vander Meulen
        - » Jim Morgan
        - » Vladimir Nagaslaev
      - Main Injector
        - » Dave Capista
        - » Phil Adamson
      - Recycler
        - » Martin Hu
        - » Meiqin Xiao
        - » *Cons Gattuso*

Pbars' Journey



The Antiproton Source is made up of three parts. The first is the Target Station: Fermilab creates antiprotons by striking a inconel target with protons. Second is the Debuncher Ring: This triangular shaped ring captures and cools the antiprotons coming off of the target. The third is the Accumulator: This is the storage ring for the antiprotons.

The Transfer lines are made the AP3, AP1, P2 and P1 lines. Currently not all of these beam lines have the capability of ramping their devices.

The Main Injector and Recycler are the last elements in the transfer chain. The Main Injector decelerates the beam down to Recycler energy, which is ~40 MeV lower the Accumulator. The beam is then stored in the Recycler until it need for a Collider shot.

Goals of Rapid Transfer Task Force

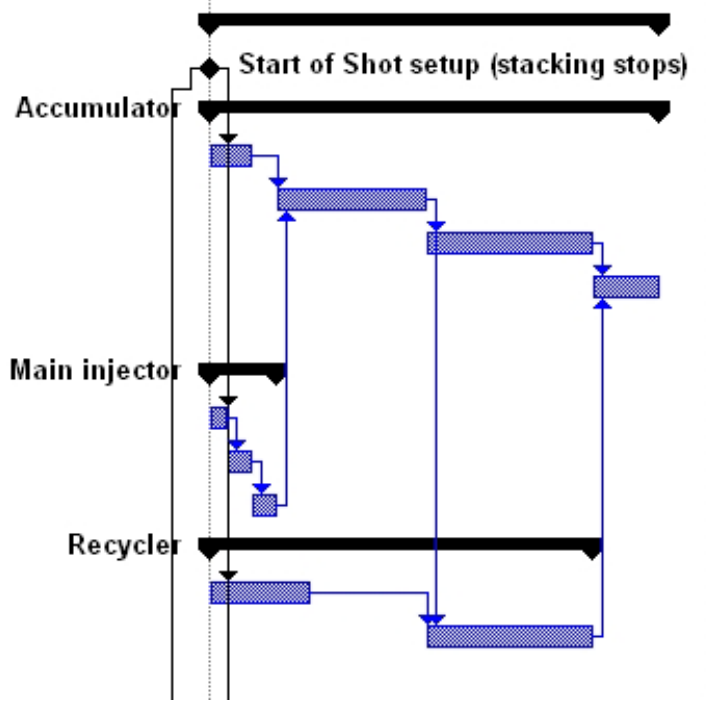
- Charge of the Task force
  - Minimize interruption to Stacking
    - Time (2 % interruption to stacking)
      - Every 2.5 Hours of stacking the shot setup/transfer should take ~ 3min.
  - Maximize Efficiency
    - Accumulator to Recycler overall transfer efficiency of greater than 95%.
      - This includes not only the machine to machine transfer efficiency, but also the beam lifetime during the transfers.

We hope to meet these goals within the next 3-4 months.

Pbar Transfer Time Management

- Process as of 1 year ago

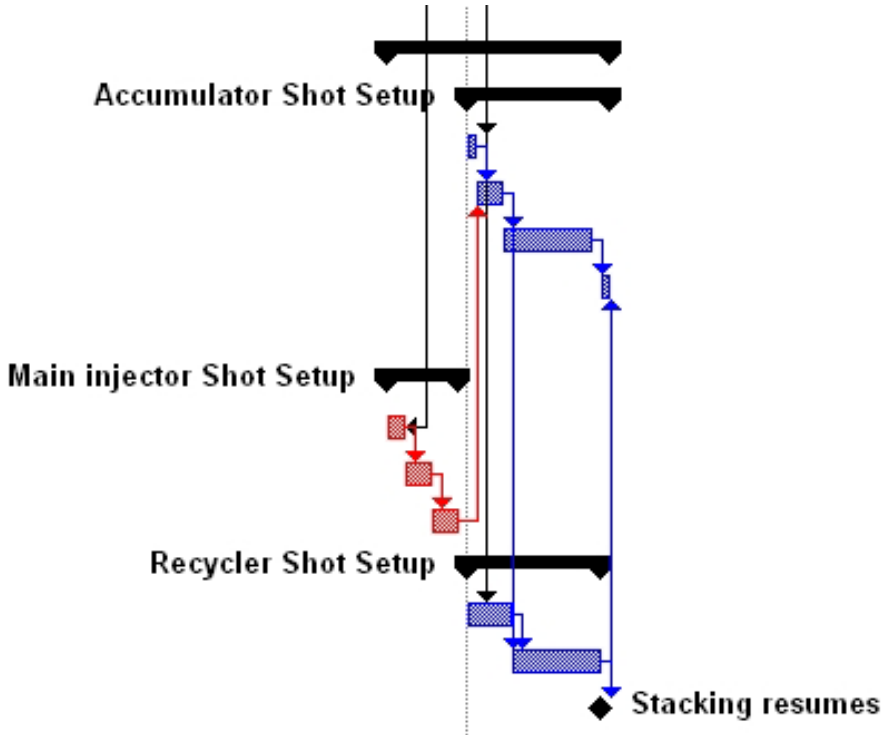
Shot Setup (1 year ago)	**54 mins**
Start of Shot setup (stacking stops)	0 days
Accumulator	**54 mins**
Shot setup	5 mins
Reverse Proton Tune Up	18 mins
Transfers (5 transfers 4 min per)	20 mins
Return to stacking	8 mins
Main injector	**8 mins**
Shot setup	2 mins
set Delta P/P	3 mins
Setting extraction position	3 mins
Recycler	**46 mins**
Set up RF	12 mins
Transfer (per transfer)	20 mins



Pbar Transfer Time Management

- Process today

Shot Setup (to day)	**15 mins**
Accumulator Shot Setup	**15 mins**
Shot setup	1 min
Reverse Proton Tune Up	3 mins
Transfers (5 transfers 2 min per)	10 mins
Return to stacking	1 min
Main injector Shot Setup	**23 mins**
Shot setup	2 mins
set Delta P/P	3 mins
Setting extraction position	3 mins
Recycler Shot Setup	**14 mins**
Set up RF	3 mins
Transfer (per transfer)	10 mins
Stacking resumes	0 days



Changes made to the process

- Pbar
  - Time aspect
    - Sequencer changes
      - Modified setup portion of process to include everything that can be setup before stacking stops.
      - Purged sequencer of all non essential commands
        - » Literally thousands of device manipulations
      - Return to stacking trimmed down to absolute minimum number of commands to get us stacking; remainder is completed after beam has been established.
      - Usage of ACL (Accelerator Command Language) script.
      - Increased the amount of automation in the Sequencer which reduces the amount interaction with operators; this reduces the shot setup time and increases the overall consistency of transfers.
      - Transfer portion of sequencer now highly automated. Loop control now done by device state instead of human interface.

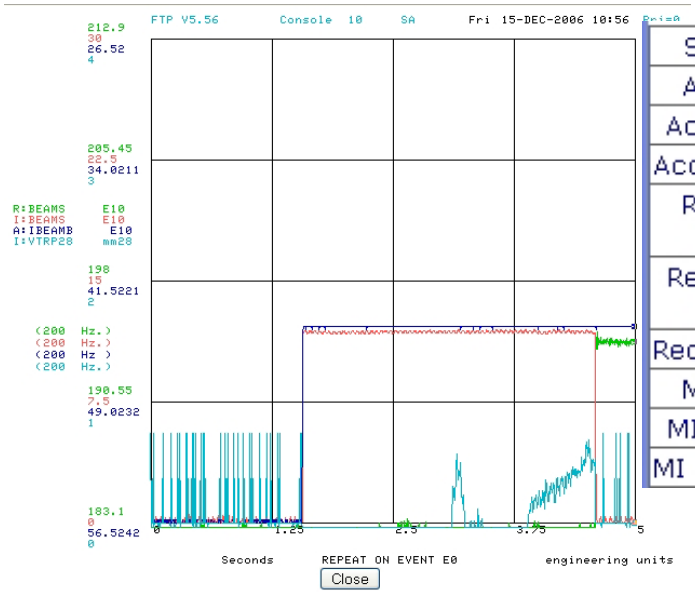
Changes made to the process

- Main Injector
  - Shot setup process
    - The entire shot setup is now completed before stacking stops, so it does not impact the stacking to stacking time.
- Recycler
  - Shot setup process
    - RF manipulation at injection were restructured to reduce the time between transfers.
    - Improve hand shaking between RR and Accumulator via state devices.

Upgrades to Hardware

- Pbar
  - Transfer lines have a new BPM system that allows us see pbars.
    - AP3, AP1, P2 and the P1 line
  - Ramp Cards have been installed for correction and major bend elements.
    - P2 and P1 lines, AP1 implementation in underway
- Main Injector
  - New Ring BPM system that also allows the Main Injector to see 2.5 MHz structure Beam.
    - This has allowed us for the first time to record BPM positions for Pbars in the Machine.

Transfer Efficiencies



Stages\Sets	Transfer #1	Transfer #2	Transfer #3	Transfer #4	Transfer #5
Acc. Vertical	2.634	2.102	1.190	.950	.859
Acc. Horizontal	8.336	7.472	4.956	4.310	3.569
Acc. Longitudinal	1.584	1.693	1.652	1.743	1.542
Rec. Vertical Flying Wire	6.900 10.582	6.084 7.775	7.561 6.713	7.789 6.736	8.072 5.203
Rec. Horizontal Flying Wire	8.448 7.036	8.036 6.523	9.607 5.282	9.844 4.912	10.061 3.454
Rec. Longitudinal	.000	.000	.000	.000	.000
MI 8 Vertical	7.331	7.066	5.523	7.253	3.667
MI 8 Horizontal	8.242	11.592	5.321	5.246	4.214
MI 8 Longitudinal	1.301	1.441	1.384	1.405	1.427

Description	Transfer #1	Transfer #2	Transfer #3	Transfer #4	Transfer #5	Sum / Average	Units
A:IBEAMB sampled on $91 (A:IBEAM1)	51.788	44.387	36.188	27.588	17.988		E10
A:IBEAMB sampled on $94 (A:IBEAM2)	44.387	36.188	27.588	17.988	10.987		E10
MI DCCT SMALL BEAM (I:BEAMS)	7.067	7.809	8.310	9.374	6.705	39.266	E10
I:BEAM6	6.927	7.578	8.264	9.366	6.714		E10
R:BEAME0[0] pre xfer	101.211	107.816	115.271	123.144	131.637		E10
R:BEAME0[1] post xfer	108.030	115.362	123.240	131.962	138.159		E10
Accumulator to MI Transfer Efficiency at Injection	95.506	95.237	96.626	97.645	95.788	96.160	%
MI Efficiency	98.006	97.042	99.448	99.917	100.138	98.910	%
MI to RR Transfer Efficiency	96.489	96.618	95.889	94.065	97.274	96.067	%
Accumulator to Recycler transfer eff	92.153	92.017	92.654	91.850	93.177	92.370	%
Pbars unstacked (transfer)	7.400	8.200	8.600	9.600	7.000	40.800	E10

Current Measurements/Areas of Interest

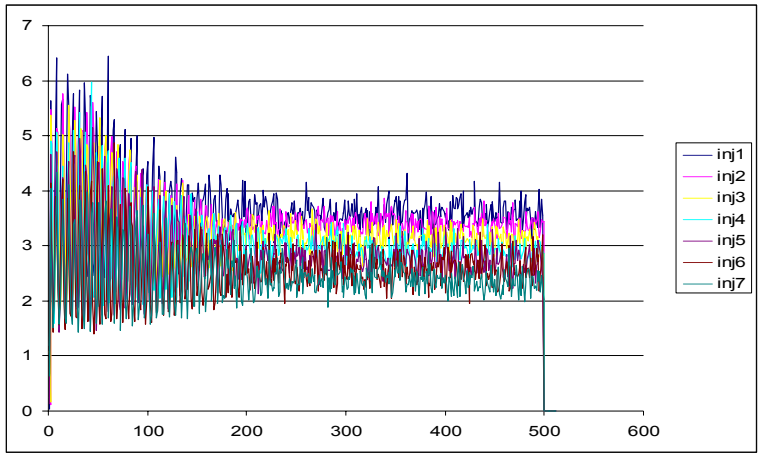
- Main Injector to Recycler Transfers
  - Lattice matching
    - Main Injector to the R22 Line
    - R22 line to the Recycler
    - Recycler Optics corrections
  - Admittance Maximization

- Accumulator to Main Injector Transfer
  - Lattice matching
    - Depression measurement in the AP3, AP1, P2 and P1
    - Finalize lattice function

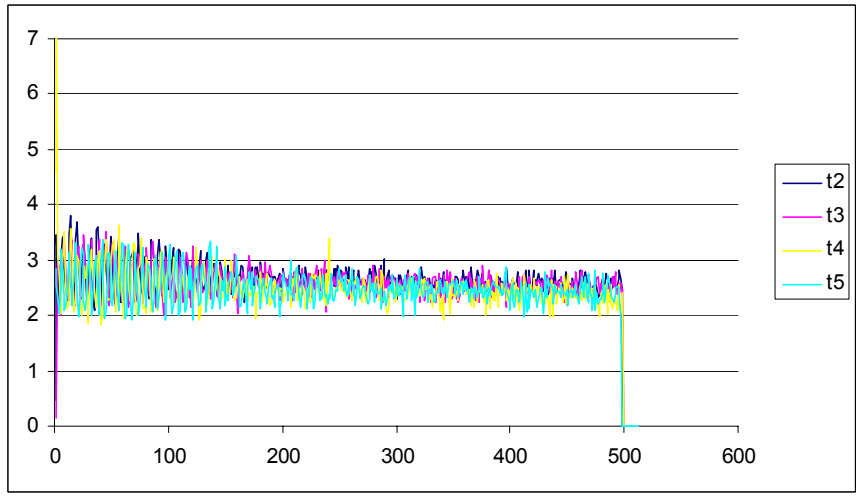
Antiproton transfers to the Recycler
MI IPM σ (mm) vs. turn

- Horizontal Plane

9/29/2006

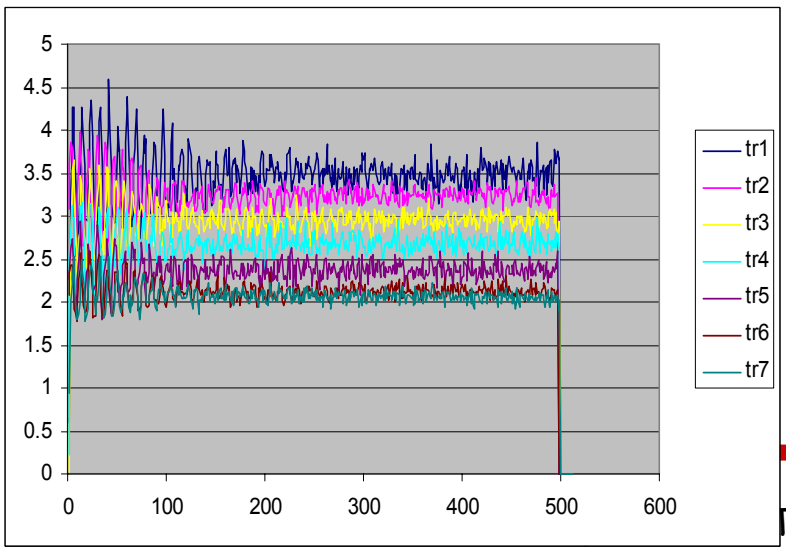


10/2/2006

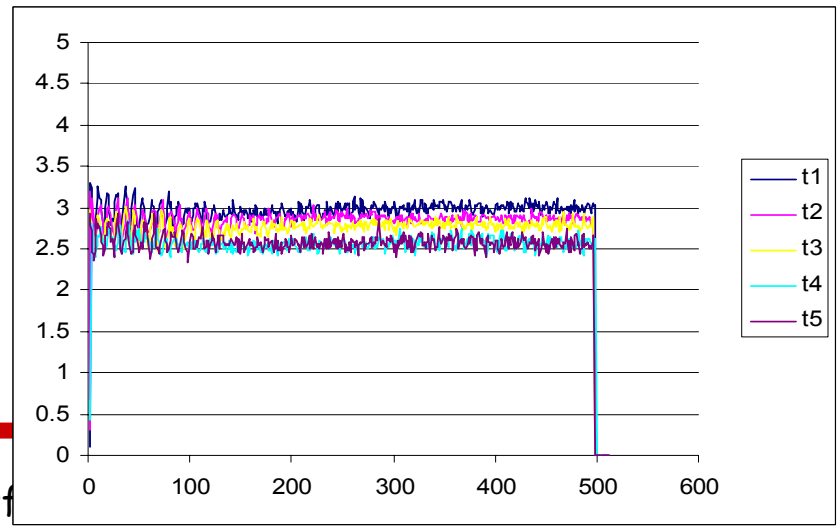


- Vertical Plane

9/29/2006

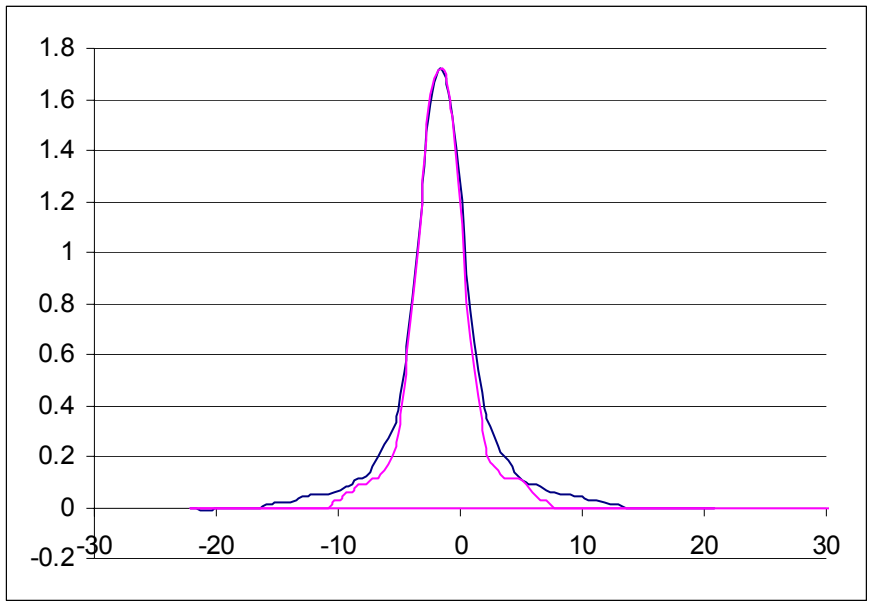


10/2/2006



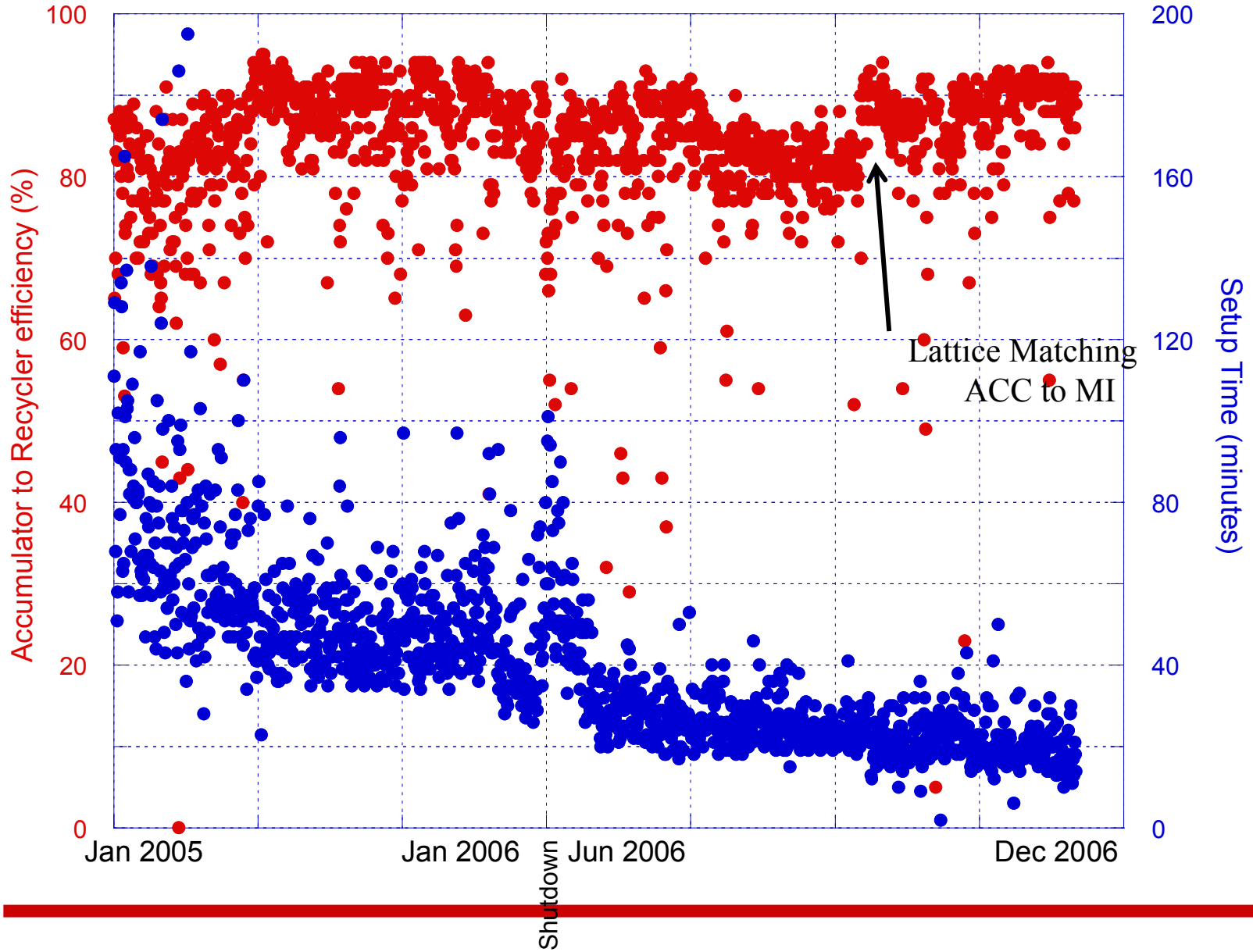
Transf

MI HFW 3rd transfers, 9/29/2006 vs. 10/2/2006

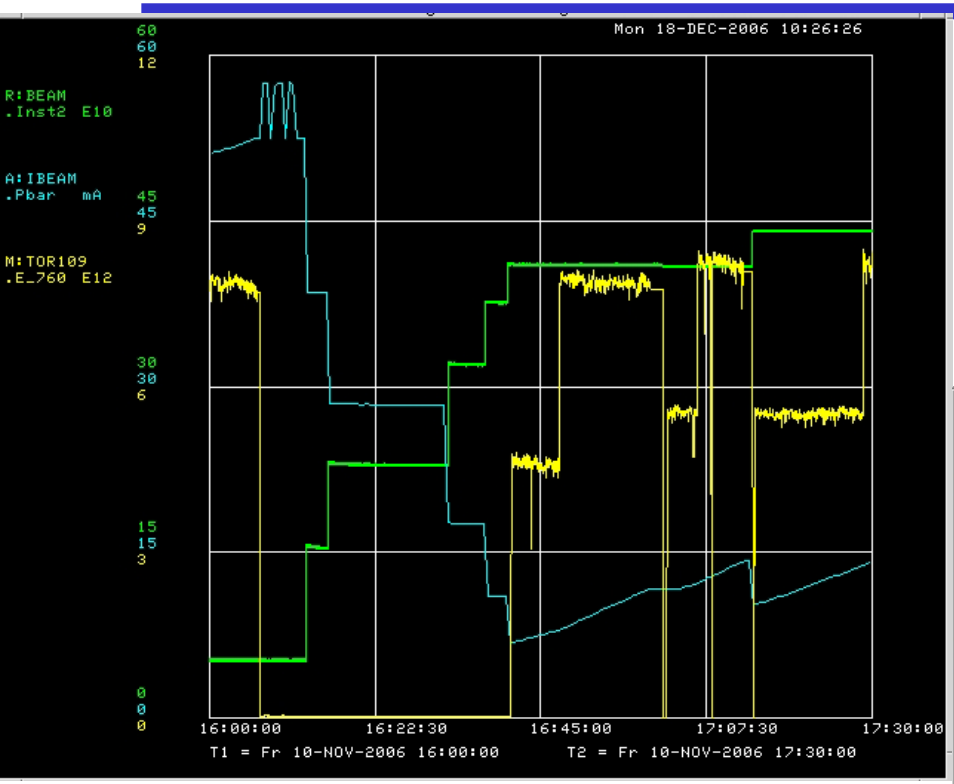


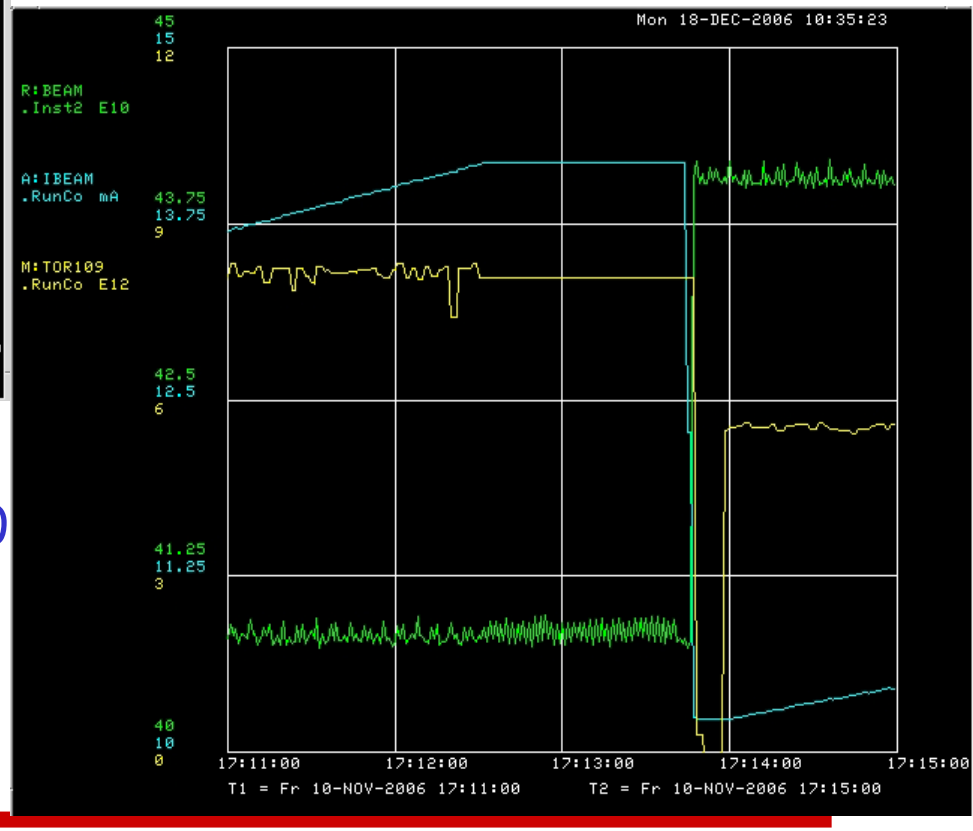
Recycler shots

Transfer Efficiency and Setup Time



Da Stunt





- Nov 10th 2006
  - One Rapid transfer of ~4 E10 was completed to the Recycler in 91 sec (stacking to Stacking).

Improvements in the works

- Items current being worked upon
  - Stacking between individual Recycler Transfers.
    - This improves effective stacking rate
  - Increase the amount voltage of ARF4 to reduce the bunch length.
    - Minimize effect of EKIK rise time, thus improving the efficiency.
  - Increase the effective aperture through out the chain of beamlines/machines.
    - Allows us greater flexibility in the in the extraction process, both in speed of transfers and efficiency.
  - Turn by Turn Damper in the Main Injection
    - Allows us to eliminate routine reverse proton tune-ups. With the Damper system active the emit growth during transfers will be minimized.